MAY 21, 1990

CHEMICAL & ENGINEERING

NEWS

Chemical industry earnings down in first quarter
Page 12

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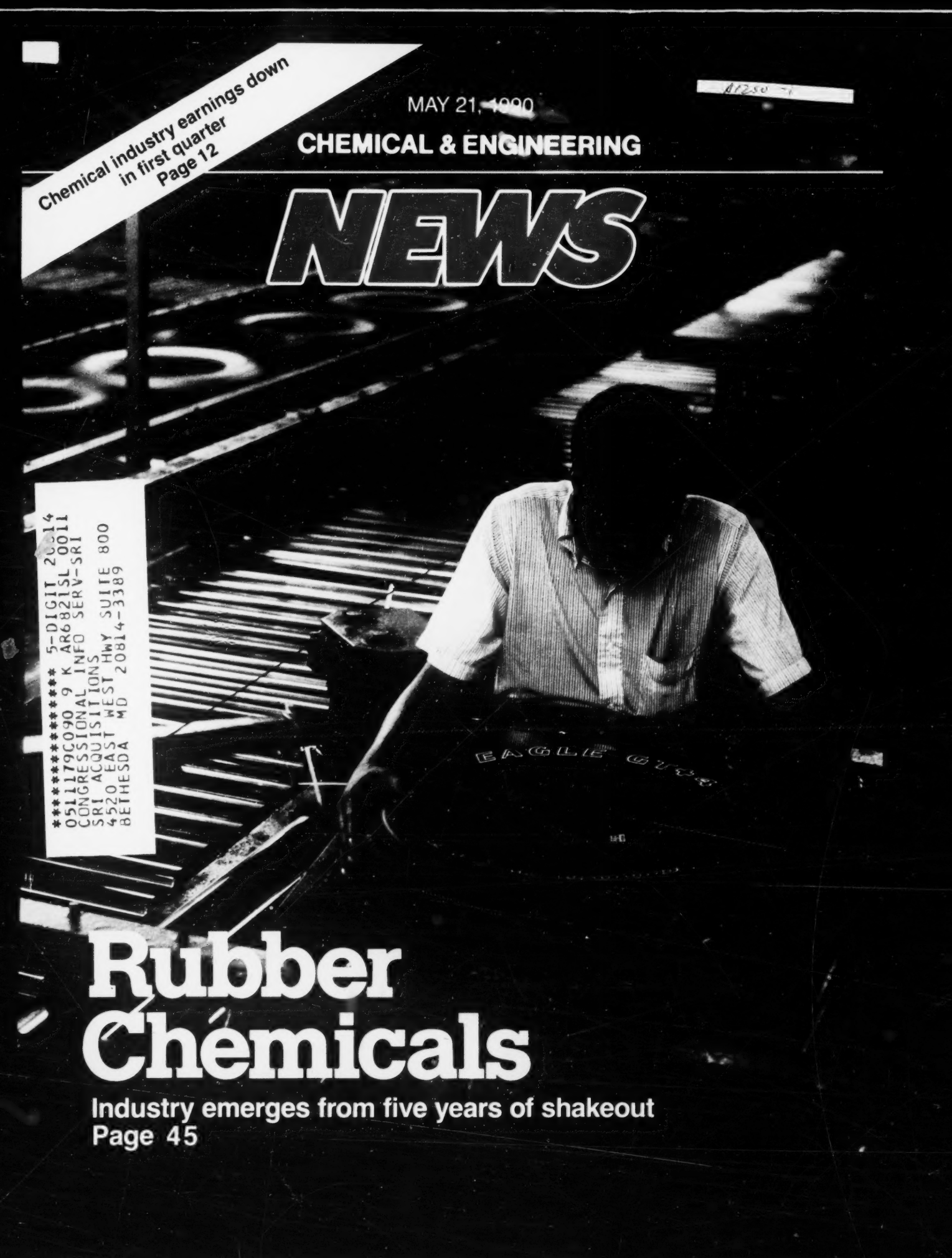

Rubber Chemicals

Industry emerges from five years of shakeout
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CHEMICAL & ENGINEERING
NEWS
MAY 21, 1990

Volume 68, Number 21
CENEAR 68 (21) 1-98
ISSN 0009-2347

News of the Week

- **Tufts researcher Thereza Imanishi-Kari may face criminal inquiry as part of ongoing probe into allegations of scientific misconduct relating to paper published in 1986 by her, Nobel Laureate David Baltimore, and coworkers.** Page 6
- **CIA report assesses East Europe's economic prospects, says formidable barriers to genuine economic reforms still lie ahead.** Page 7
- **Library of Congress ponders National Library of Science & Technology** Page 7
- **Ciba-Geigy to sell its San Jose, Calif.-based Spectra-Physics subsidiary.** Page 8
- **West Germany's BASF, Bayer, and Hoechst form a consulting venture for the recycling of plastic wastes.** Page 8

Cover: Photo courtesy of Goodyear

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Business

Earnings of major U.S. chemical firms were down again in the first quarter; U.S. aerosol production leveled off in 1989; Occidental's Ray Irani talks about company's philosophy for success; caustic supply will be restrained by sagging chlorine demand; some critical issues confront thermoplastic color concentrates producers; Taiwan's chemical industry is setting up operations overseas. **Page 12**

Government

U.S. motor fuels policy is being scrutinized by newly formed Alternative Fuels Council; OTA report finds policy lacking in high-temperature superconductivity; FDA permits use of zidovudine to treat AIDS in children; focus groups are helping write long-awaited acid rain report. **Page 25**

Science/Technology

From the Boston meeting: Advances in homogeneous catalysis broaden scope of process chemistry; progress in mild gasification approach renews interest in coal conversion; unique form of cellulose produced in fermenters is nearing commercialization; laser-based molecular fluorescence spectrometry offers sensitive new analytical methods; chemical markers produced when foods are heated can establish sterility of processed food. In other news: puzzle of ozone hole's hidden chlorine chemistry appears to be solved. **Page 30**

Books

Current-day science in the U.S.S.R. is reassessed and critiqued in two books, "Techno-diplomacy: US-Soviet Confrontations in Science and Technology" and "Soviet Science on the Edge of Reform." **Page 69**

Product Report

Although many mergers, restructurings, and other changes have occurred to the U.S. rubber-processing chemicals industry in the past five years, the industry is strong and is slowly growing. **Page 45**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director
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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. $60, 2 yr. $108, outside U.S. 1 yr. $93, 2 yr. $174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $9.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Spokesman for chemistry

SIR: On reading James Krieger's report (C&EN, Jan. 29, page 28) of Roald Hoffmann's remarks at the Honolulu symposium on the public's perception of chemistry, I could only think that Hoffmann must be bucking for a second Nobel Prize—for peace! If he continues with his humble, humane approach to the public's fear of our profession and its attacks on our activities, he might just gain sufficient credibility to bring this era of confrontation to an end. Hoffmann has my vote as chief spokesman for the profession.

David M. Mog
Arlington, Va.

Attracting scientists

SIR: A continuum of explanations has appeared regarding the failure of our educational systems to produce high-quality chemists, physicists, and engineers. Buried among these explanations is money; I believe money is the principal factor. Youngsters do not see an environment that is attracting them to the sciences.

In today's heterogeneous societies, with childcare, nursery schools, busing, etc., youngsters are befriending a large spectrum of children from a variety of socioeconomic backgrounds. When children are invited to each others' homes, they see the gambit—from subsidized city housing to magnificent estates.

Whom do you find living in the beautiful homes? Which children go on winter vacations to ski resorts or to tropical paradises? Which families have summer homes, fancy cars, live-in help, inground pools, etc.? Which children go to posh sleepaway camps, private schools, and expensive colleges? Whose children get fancy cars when they reach 16 or enter college?

Often these families are headed by physicians, dentists, veterinarians, lawyers, accountants, investment bankers, and successful business people. Very few are the working chemist or engineer unless they won the state lottery; and TV sitcoms help reinforce this picture. Youngsters are impressionable; parents are too. Scientists don't lead the so-called great life; and if that's what you want, you'd better look elsewhere for a profession.

When all this is coupled with the hardships associated with majoring in science or engineering in college, one could almost conclude that only the misguided wind up in these disciplines aiming to get a Ph.D. And maybe there's some truth to that. An adolescent who is strongly intimidated by the people interactions associated with being a lawyer, physician, dentist, Wall Street wheeler-dealer, etc., is much more comfortable as the loner scientist—the "nerd" syndrome. Maybe society is generating too many well-rounded youngsters, reducing the pool of talent who consider becoming scientists.

Look at the ACS statistics (C&EN, July 3, 1989, page 31). Three quarters of the nonacademic chemistry Ph.D.s with 15 to 19 years of experience beyond the B.S. degree (men and women in their late thirties and early forties) earn less than $61,000. Meanwhile, youngsters graduating from the high end of their law schools are starting today at over $80,000, at least in major New York City law firms. There are no mechanisms in place today where a 24- or 25-year-old Ph.D., regardless of what school, which professor, or how good, can start a career at a major chemical company at over $80,000. When scientists can earn what lawyers, physicians, dentists, and investment bankers earn, or are perceived to earn, the concerns about the future supply of high-quality scientists will disappear.

Robert Rabinowitz
Technical Director, Flocculants and Reagents, American Cyanamid Co.

Good teachers, better students

SIR: I would like to respond to Tom Castle's letter (C&EN, March 12, page 2) regarding the statements he made about high school teachers. I love to teach science and kids, but teaching is not easy if you do it right. I have been a high school chemistry and physics teacher for six years, a graduate teaching assistant, and this year have taught organic chemistry part time at a local community college. Omitting my part-time teaching at night, I average 10 working hours a day at school, teaching six classes with four different subject preparations. I also av-

Correction

• April 30, page 35: California Institute of Technology should have been ranked eighth on the listing of major producers of Ph.D. chemists in 1988–89 with 34 such graduates.

Chemical Earnings Tumble In First Quarter

Declining prices, rising costs, slipping sales have combined to push profits down at many chemical companies; oil and diversified firms also see fall

William J. Storck,
C&EN Northeast News Bureau

The first quarter was pretty much on target for chemical company earnings. A downturn in chemical earnings was expected and that's what happened. Various combinations of falling prices, rising costs, and declining sales volumes caused earnings to decline at many firms. However, most chemical executives still see a good year in total.

Nevertheless, the first quarter was not a particularly good way to start the year. Earnings at 30 major chemical companies surveyed by C&EN fell an average of 26% from last year's first quarter. The bottom line was also down at oil companies and diversified firms that produce chemicals. And earnings suffered at major pharmaceutical companies, although this was a case of one company's results dragging down the whole group.

Government data tell part of the story. Prices for chemicals and allied products in the first quarter averaged 2.0% lower than they did in the same period in 1989. And chemical production was up only a little more than 1% from last year's first quarter.

More telling perhaps were the shipments and inventories figures released by the government for the first quarter. The Commerce Department reports that shipments of chemicals and allied products in the first three months of this year were essentially level with the same period in 1989. And for industrial chemicals, shipments for the first quarter fell 4.6% on a seasonally adjusted basis.

At the same time, inventories increased in chemicals and allied products, probably more than soaking up the increase in production. Inventories of chemicals and allied products rose about 2% over the previous year. And inventories for industrial chemicals were essentially unchanged from the year-earlier quarter.

Continued softness in downstream and end-use markets was the key to chemicals' performance. Automobile sales and production remained at low levels and the residential housing market continued soft. Commercial building also was sustaining lower levels than in the past few years.

Demand in the agricultural sector, though up from just a few years ago, still did not provide the boost needed for earnings at the major fertilizer companies. And durable goods orders and shipments were well down from the first three months of 1989.

Since all of these markets are big users of chemicals, it is no wonder that the industry had its problems during the quarter.

Adding to that was the export situation. Although shipments of many chemical products out of the U.S. seemed to hold up on a volume basis and, in fact, increased in some cases, the selling price of those exports fell, according to many industry observers.

Chemical industry leaders for first-quarter 1990

Sales

Rank 1990		$ Millions	Rank 1989
1	Dow Chemical	$4900.0	1
2	Monsanto	2286.0	2
3	Union Carbide	2173.0	3
4	W. R. Grace	1507.3	4
5	American Cyanamid	1272.7	5
6	Hercules	771.4	7
7	Air Products	713.1	10
8	Rohm & Haas	694.4	9
9	Arco Chemical	685.0	8
10	Quantum Chemical	682.8	6

Earnings[a]

	$ Millions	Rank 1989
Dow Chemical	$462.0	1
Monsanto	194.0	2
Arco Chemical	125.0	4
Union Carbide	94.0	3
American Cyanamid	90.9	5
Air Products	54.3	9
Rohm & Haas	54.1	8
Ethyl	52.4	10
International Flavor	41.6	13
Morton International	39.1	14

Profitability

	Earnings as a % of sales	Rank 1989
Arco Chemical	18.2%	4
International Flavor	17.2	3
Georgia Gulf	14.9	2
Great Lakes Chemical	13.6	1
Loctite	11.8	7
Betz Laboratories	10.7	8
Nalco Chemical	10.4	9
Dow Chemical	9.4	4
Vista Chemical	8.8	6
Morton International	8.7	16

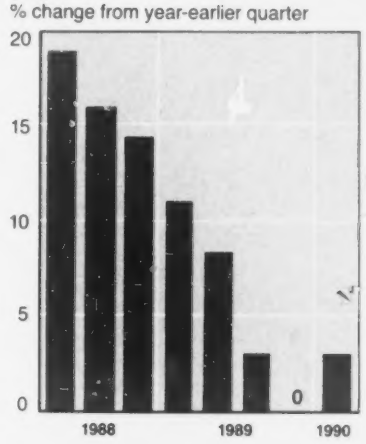
Note: Based on 30 chemical companies listed on page 14. a After taxes.

Chemical industry 1990 first-quarter results

- Sales rose 3%
- Earnings dropped 26%
- Profitability fell to 7.3%
- Production increased 1%
- Prices were down 2%

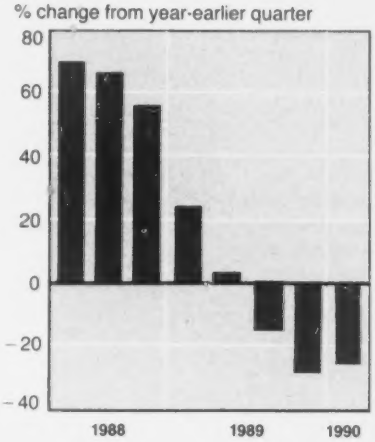
Sales

% change from year-earlier quarter



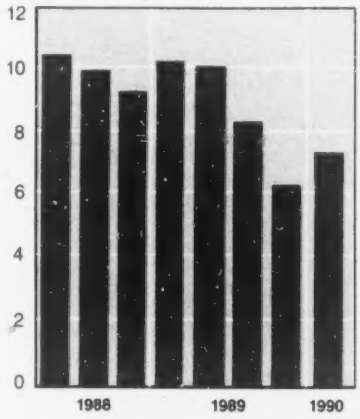
Earnings

% change from year-earlier quarter



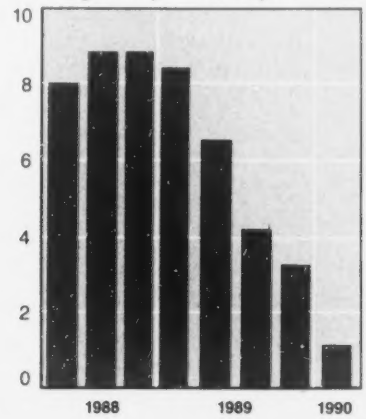
Profit margins

After-tax earnings as % of sales



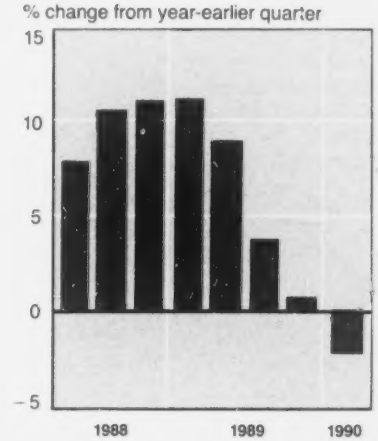
Production

% change from year-earlier quarter



Prices

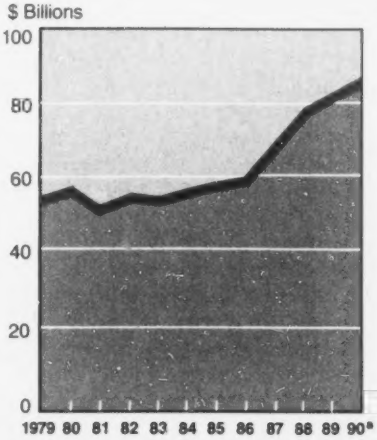
% change from year-earlier quarter



Sales in 1990 will rise about 4% while earnings will be flat, lowering profit margins to about 8.3%

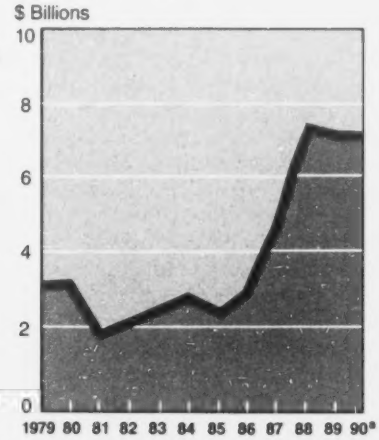
Annual sales

$ Billions



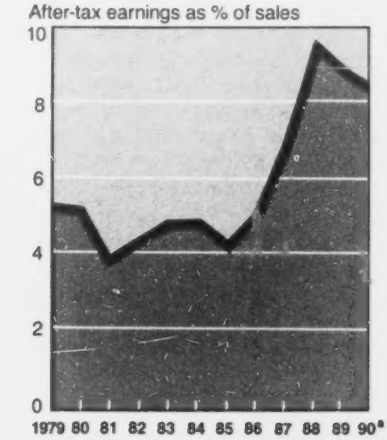
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on 30 chemical companies listed on page 14. a C&EN estimates.

Earnings at major chemical companies fall 26% in first quarter

	FIRST-QUARTER 1990						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989	Sales	Earnings	1990	1989
Air Products	$ 713.1	$ 54.3	7%	5%	7.6%	7.7%	6%	−6%	7.7%	8.7%
American Cyanamid	1,272.7	90.9	3	7	7.1	6.9	4	−4	6.3	6.7
Arco Chemical	685.0	125.0	−2	8	18.2	16.6	−6	−18	15.6	17.8
Betz Laboratories	143.3	15.4	15	17	10.7	10.6	15	15	10.8	10.8
Cabot	455.1	15.0	−16	−47	3.3	5.2	−4	−48	2.1	3.9
Chemed	143.9	4.2	1	−21	2.9	3.7	9	15	4.2	4.0
Crompton & Knowles	94.4	6.9	8	30	7.3	6.1	6	41	7.2	5.4
Dow Chemical	4,900.0	462.0	9	−38	9.4	16.6	5	−17	12.2	15.4
Ethyl	609.7	52.4	7	3	8.6	9.0	7	−3	9.4	10.4
First Mississippi	116.9	1.3	−1	−85	1.1	7.3	26	−97	0.2	8.4
H. B. Fuller	181.5	1.6	2	−16	0.9	1.1	7	−16	2.0	2.6
Georgia Gulf	251.6	37.4	−21	−32	14.9	17.4	−10	−17	16.8	18.2
B. F. Goodrich	589.8	16.2	−4	−68	2.7	8.3	−5	−41	5.7	9.2
W. R. Grace	1,507.3	32.6	8	8	2.2	2.2	6	6	3.3	3.3
Great Lakes Chemical	252.3	34.3	74	20	13.6	19.7	60	19	14.3	19.1
Hercules	771.4	33.7	4	−25	4.4	6.1	11	−44	2.5	5.0
International Flavors	241.4	41.6	6	8	17.2	16.9	5	8	16.0	15.6
International Minerals	371.7	18.7	43.8	−21.8	5.0	9.2	31	−16	5.2	8.0
Loctite	133.9	15.8	15	12	11.8	12.1	10	17	12.2	11.5
Lubrizol	355.5	29.1	4	−5	8.2	8.9	7	−4	7.5	8.3
Monsanto	2,286.0	194.0	1	−13	8.5	9.8	3	2	7.1	7.2
Morton International	447.1	39.1	12	13	8.7	8.7	11	−3	7.9	9.0
Nalco Chemical	284.8	29.7	14	18	10.4	10.1	10	17	11.2	10.5
Olin	636.0	32.0	0	−6	5.0	5.3	3	18	4.9	4.3
Petrolite	72.0	3.6	0	18	5.0	4.3	−1	11	4.4	3.9
Quantum Chemical	682.8	5.8	−16	−92	0.8	8.8	−20	−76	3.6	11.9
Rohm & Haas	694.4	54.1	2	2	7.8	7.8	3	−20	6.6	8.5
Union Carbide	2,173.0	94.0	−3	−53	4.3	9.0	1	−36	6.0	9.5
Vista Chemical	183.8	16.2	−7	−50	8.8	16.4	−4	−30	12.0	16.4
Witco	395.2	14.5	−1	−15	3.7	4.3	−1	−10	4.6	5.0
TOTAL	**$21,646.0**	**$1571.5**	**3%**	**−26%**	**7.3%**	**10.1%**	**3%**	**−18%**	**7.9%**	**9.9%**

a Earnings from operations excluding significant nonrecurring and extraordinary items. b Earnings as a percentage of sales.

Although all of this resulted in a large drop in chemical earnings, it must be remembered that the earnings for the first quarter are still being compared with earnings from a very heady period of growth for the industry that lasted into the second quarter of 1989.

Combined earnings for C&EN's sample of 30 chemical companies fell 26% to $1.57 billion on a sales increase of about 3% to $21.6 billion. The result was that the average profit margin (after-tax earnings as a percentage of sales) dropped to 7.3% in the first quarter of 1990 from 10.1% in the comparable period last year.

Though the nearly three percentage point drop seems large, an average profit margin of 7.3% is still high for the chemical industry on a historical basis.

Further clouding the picture is the split between the large and commodity-oriented companies and the smaller to medium-size companies. If just two companies, Dow Chemical and Union Carbide, are pulled from the list, the remaining 28 firms had an average earnings decline of just 14%. Then take out Quantum with its huge 92% earnings fall and the decline for the 27 firms remaining drops to 9%. Although 16 of the 30 companies surveyed showed declines in earnings, only eight of these were greater than the average for the full list of companies. Thus, these eight had a disproportionate effect on the average decline for the group.

And among the 14 companies with earnings growth in the quarter, half of them reported growth rates in the double-digit range.

Also somewhat encouraging was that the average earnings decrease of 26% for the first quarter was less than the 29% year-to-year decline registered in the previous quarter. And although sales were up just 3% in the first quarter this year compared with a year earlier, that's better than the no-growth situation of the previous quarter.

In addition, first-quarter earnings for the 30 major companies increased an average of almost 26% over fourth-quarter 1989, and sales

Earnings decline for most oil companies

	FIRST-QUARTER 1990					
	Sales	Earnings[a]	Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989
OIL AND GAS COMPANIES						
American Petrofina	$ 896.3	$ 26.2	25%	−46%	2.9%	6.8%
Amoco	7,129.0	466.0	9	2	6.5	7.0
Chevron	9,300.0	473.0	21	51	5.1	4.1
Exxon	26,713.0	1280.0	20	0	4.8	5.7
Kerr-McGee	811.8	27.1	13	−20	3.3	4.7
Mobil	14,908.0	400.0	6	−7	2.7	3.1
Occidental Petroleum	5,159.0	108.0	0	61	2.1	1.3
Shell Oil	5,754.0	203.0	11	−44	3.5	7.0
Sun Co.	3,110.0	71.0	17	−12	2.3	3.1
Texaco	9,156.0	328.0	−5	−24	3.6	4.5
Unocal	2,643.0	77.0	1	−13	2.9	3.3
TOTAL	**$85,580.1**	**$ 3459.3**	**11%**	**−3%**	**4.0%**	**4.6%**
DIVERSIFIED MANUFACTURERS						
Allied-Signal	$ 3,055.0	$ 129.0	4%	2%	4.2%	4.3%
Borden	1,892.5	63.1	4	7	3.3	3.2
Du Pont	9,404.0	615.0	8	−14	6.5	8.3
Eastman Kodak	4,111.0	199.0	−2	−6	4.8	5.0
Engelhard	658.5	14.8	12	3	2.2	2.4
FMC	813.5	38.0	−3	12	4.7	4.1
Ferro Corp.	279.7	6.0	3	−51	2.1	4.6
3M	3,164.0	335.0	5	5	10.6	10.5
PPG Industries	1,478.0	125.3	1	−3	8.5	8.9
Tenneco	3,602.0	134.0	9	23	3.7	3.3
Vulcan Materials	232.0	18.7	7	19	8.0	7.2
TOTAL	**$28,690.2**	**$ 1677.8**	**5%**	**−4%**	**5.8%**	**6.4%**
PHARMACEUTICAL COMPANIES						
A. H. Robins	$ 1,438.4	$ 225.0	11%	14%	15.6%	15.3%
American Home Products	1,813.4	314.5	4	12	17.3	16.0
Baxter International	1,903.0	−383.0[c]	7	def	def	5.7
Bristol Myers-Squibb	2,457.7	409.1	9	19	16.6	15.2
Merck	1,758.4	403.8	12	19	23.0	21.7
Pfizer	1,482.0	251.9	3	5	17.0	16.8
Rorer Group	277.7	11.1	15	14	4.0	4.1
Shering-Plough	865.1	150.4	4	20	17.4	15.1
Upjohn	772.9	114.3	4	10	14.8	14.0
Warner Lambert	1,100.0	120.3	8	19	10.9	9.9
TOTAL	**$13,868.7**	**$ 1617.3**	**7%**	**−12%**	**11.7%**	**14.3%**

a Earnings from continuing operations excluding significant nonrecurring and extraordinary items. b Earnings as a percentage of sales. c Includes nonrecurring item.

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 21 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 10 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

rose slightly less than 8%. And first-quarter profitability of 7.3% was up substantially from 6.2% for the same companies in the fourth quarter of 1989. Although quarter-to-quarter comparisons can be affected by seasonal fluctuations—for instance, the first quarter is historically better than the preceding fourth quarter—this is much improved from the 6% sales increase and 15% earnings increase recorded between the comparable quarters of 1988 and 1989. Profit margins rose to 10.1% in the first quarter of 1989 from 9.3% in fourth-quarter 1988.

Chemical company earnings, however, had the largest drop of the industry groups surveyed by C&EN. At 10 pharmaceutical firms, combined earnings fell 12% from last year's first quarter to $1.62 billion on a sales increase of 7% to almost $13.9 billion. This is deceptive, however, since these results include a huge nonrecurring charge at Baxter International that accounted for all of the earnings decline at these 10 firms. Profit margins for the drug companies averaged 11.7%, down from 14.3% in the first quarter of 1989.

For 11 diversified manufacturers that produce chemicals, combined earnings fell 4% in the quarter to $1.68 billion on a 5% sales increase to $28.7 billion. Profitability for these firms averaged 5.8% for the quarter, down from an average of 6.4% in the same period of 1989.

For 11 petroleum and gas companies, combined first-quarter earn-

ings fell 3% from the same period last year to $3.46 billion on a sales increase of 11% to $85.6 billion. This caused profit margins to decline to an average of 4.0% in the first quarter this year from 4.6% in the same period in 1989. Oil company results for chemical operations further underscored the weakness of commodity chemicals in the first quarter.

For eight of the oil firms that report chemical earnings—Amoco, Chevron, Exxon, Mobil, Occidental, Shell, Texaco, and Unocal—these results declined 48% to a total of $773 million in the first quarter. The decline was headed by Texaco's 83% drop to $16 million. This was followed by declines of 63% to $6 million at Unocal; 56% to $98 million at Shell; 55% to $181 million at Exxon; 54% to $98 million at Mobil; 49% to $80 million at Amoco; 34% to $186 million at Occidental; and 6% to $123 million at Chevron. Chevron, however, says that chemical earnings for the first quarter of this year include some one-time benefits from licensing arrangements, stemming from the restructuring of the firm's agricultural chemical operations. Otherwise, earnings declined on sharply lower prices for aromatic and olefin commodity chemicals.

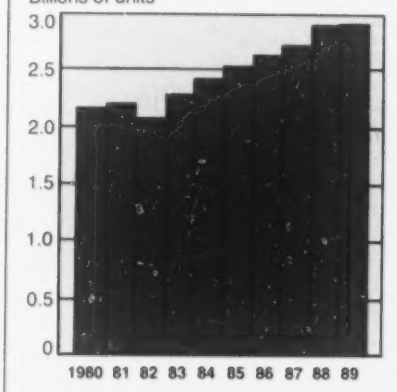
Among the chemical companies, the weaker commodity chemical prices and volumes were cited by Union Carbide and Dow, among others.

For the remainder of the year, companies are fairly optimistic, given the circumstances. At Dow, president and chief executive officer Frank P. Popoff states that 1990 will not be a record year for earnings, but that the company will post "strong, sustainable results."

Monsanto's chairman, Richard J. Mahoney, says, "While earnings were down from the same period last year, results were affected by seasonal timing shifts in our agricultural markets and slow business conditions in automotive markets. Nevertheless, we're off to a good start toward another record year for Monsanto."

At Rohm & Haas, chairman J. Lawrence Wilson says the company's performance in the first quarter confirms management's belief that its full-year operating earnings will be roughly equivalent to those of 1989. □

Aerosol production was essentially flat in 1989



Source: Chemical Specialties Manufacturers Association

Growth streak ends for aerosol industry

Aerosol production in the U.S. leveled off last year, according to the latest annual pressurized products survey from the Chemical Specialties Manufacturers Association. At CSMA's midyear meeting in Chicago, Thomas E. Moloney, director of marketing for American-National Can Co., revealed that an estimated 2.91 billion container units were filled in 1989, just about the same as in 1988. That figure confirmed predictions of a slowdown after six consecutive years of healthy growth (C&EN, April 23, page 35).

Officially, there was a small increase last year of just under 0.2% from 1988 to 2.912 billion units. The survey process is inherently uncertain, however. For example, although questionnaires were sent to 221 companies with filling lines in the U.S. and Puerto Rico, only 127 of those companies responded (compared with 151 out of 217 in 1988). The survey committee extrapolates from those responses, guided in part by production figures from container and valve manufacturers. So, given the uncertainties, it's fair to say that 1989 was a flat year for aerosols.

The relatively poor showing in 1989 is attributable mostly to a sharp drop in the personal products category. The committee estimates that 1.02 billion units of personal care products of all types were filled in 1989, down 7.7% from 1988. All major subcategories, including deodorants, hairsprays, and shaving lathers, showed declines. However, personal products continued to be the largest product category, representing about 35% of the total (compared with about 38% in 1988).

In contrast, most other major categories showed respectable growth. For example, household products, the second largest category, showed a 4.6% increase to 680 million units. Reported fillings of one subcategory—room deodorants and disinfectants—increased about 30%. Overall, the category accounted for about 23% of the total.

The third-place automotive and industrial products category, representing about 16% of the total, continued to show strong growth. Fillings increased 8.0% to 475 million units. Reported fillings of automotive cleaners of various kinds roughly doubled, to more than 31 million units. The lubricants and refrigerants subcategories also showed healthy gains.

Paints and finishes continued in fourth place. The 350 million units filled in that category accounted for about 12% of the total and represented a 5.7% increase from 1988.

The fifth-place category, insect sprays, accounted for 197 million units (about 7% of the total), up 3.7% from 1988. Food products (including pan sprays), in sixth place with 6% of the total, showed the largest percentage gain among the categories, a 12% rise to 175 million units.

The smallest category, animal products, was flat. An estimated 8 million units were filled, the same as in 1988.

However, in the miscellaneous category, the number of units filled, at 12 million units, was down 60%. The steep decline is primarily a result of refined classification procedures, with formerly "miscellaneous" products now included in other categories.

Ward Worthy

Sagging chlorine use crimps caustic soda supply

Earl V. Anderson
C&EN Northeast News Bureau

Over the next few years, demand for caustic soda will increase at a slightly higher rate than chlorine demand. For caustic soda consumers, this means a few more years of coping with caustic shortages. For chlor-alkali producers, it means finding new customers for chlorine so that caustic output will not be restrained by sagging chlorine production.

This, says Jack R. Clinton, will be the major challenge facing the chlor-alkali industry as chlorine demand in the all-important pulp and paper market declines. Unfortunately, says Clinton, who is business director for liquid caustic soda for Occidental Chemical, Dallas, the industry has only a few options available that will allow it to replace chlorine markets that are under increasing environmental pressure. The best option, he says, is tied to the fortunes of polyvinyl chloride.

Clinton told a recent meeting of the Chemical Marketing Research Association in New York City that the situation has changed dramatically in the chlor-alkali industry since 1986. Then, he says, large inventories of caustic soda were built up throughout the world. Much of this material was sold at prices one fourth what they are today.

Since then, the chlor-alkali industry has operated almost at full capacity. Nevertheless, says Clinton, all caustic output has been consumed and the huge caustic inventory has disappeared. What's more, in those four years the price of caustic has gone up fourfold.

Based on these trends and projected chlorine production, Clinton says caustic demand is outstripping available supply. And he expects this trend to continue over the next several years.

So serious is the problem that the industry is looking into the possibility of making caustic soda from sodium carbonate. Around the turn of the century, this was the preferred method of making caustic, and it remained the preferred method until electrolysis of salt replaced it.

Now, several studies are under way to evaluate the possibilities. But, he says, it remains to be seen whether the economics are attractive enough or whether caustic-from-sodium carbonate projects are even necessary over the long term.

Trying to keep chlorine and caustic production in balance with their respective demands has always been a problem for the chlor-alkali industry. A newer problem is that the industry is becoming much more global in its outlook.

There was a time, and not too long ago, says Clinton, when companies in the chlor-alkali industry could survive by looking at their own geographic—even regional—areas. This was especially true in the U.S.

But "this is a mind-set that must change—and change fast," says Clinton. To deal with its challenges, the U.S. chlor-alkali industry must adopt a global view.

There's little doubt that chlor-alkali producers are part of a global industry. World chlorine production last year was 36.7 million metric tons, with only about a third of it produced in North America.

Chlorine demand in pulp and paper will slip rapidly . . .

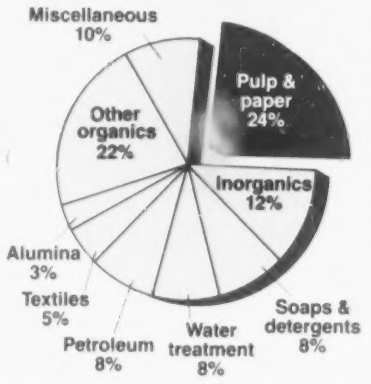
Market	% change per year through 1994
Pulp & paper	−8.6%
Inorganics	1.1
Titanium dioxide	3.4
Water treatment	0
Epichlorohydrin	2.0
Propylene oxide	2.7
Chlorinated ethanes	2.8
Chlorinated methanes	1.4
Export[a]	6.8
Vinyl chloride	4.3
Miscellaneous	0

. . . while petroleum will set the pace for caustic markets

Market	% change per year through 1994
Petroleum	3.5%
Water treatment	2.0
Soaps & detergents	1.5
Textiles	0.5
Alumina	1.0
Pulp & paper	0.6
Inorganics	1.5
Other organics	2.0
Miscellaneous	1.5

a As ethylene dichloride. Source: Occidental Chemical

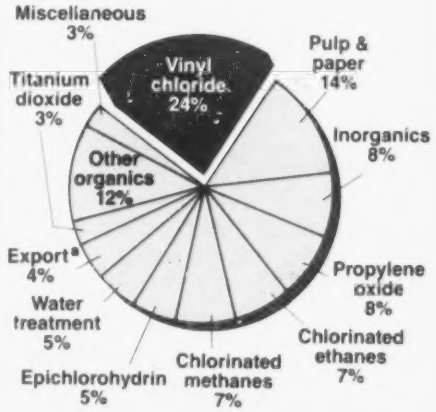
Pulp and paper take the biggest share of caustic



Total 1989 consumption = 12.3 million tons

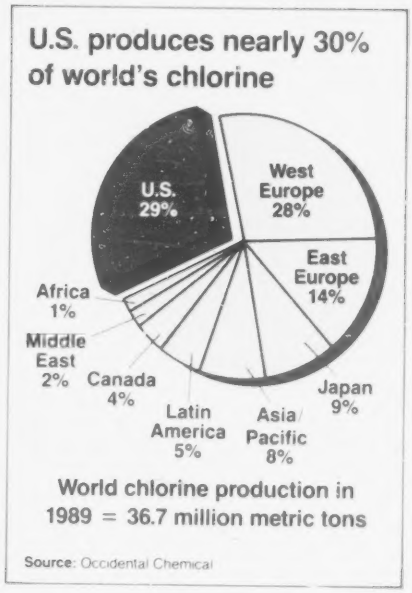
Source: Occidental Chemical

Vinyl chloride is chlorine's largest market



Total 1989 consumption = 12.1 million tons

a As ethylene dichloride. Source: Occidental Chemical



Western Europe is a close second, accounting for 28% of chlorine output last year, and East Europe is a distant third with 15% of the total. However, Clinton notes that either of the two largest U.S. producers—Dow Chemical and Occidental Chemical (OxyChem)—has capacity nearly equal to the total of all producers in either Japan or West Germany.

These two companies have nearly half the total U.S. capacity. The remainder is split among almost two dozen other companies. Some of these producers operate on a national, and even an international, basis. But others, Clinton says, limit themselves to local regions within the U.S. and have a very narrow customer base.

Worldwide, chlorine producers operated at about 87% of nameplate capacity last year. In the U.S., operating rates were slightly higher—closer to 90%. Historically, these operating rates are high, but Clinton doesn't expect them to change much over the next three to four years.

Since 1982, nearly 7500 tons per day of chlor-alkali capacity has been permanently shut down. Over the same time span, 2360 tons per day of capacity was added. The net result: a loss of more than 5000 tons per day of capacity, roughly equivalent to 14% of peak 1982 installed capacity.

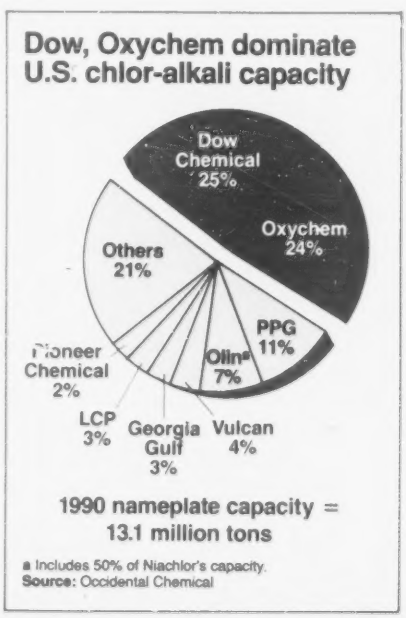
According to the Chlorine Institute, Clinton says, almost 2000 tons per day of capacity are idle in the U.S., but are viable. The institute estimates that operating capacity of the U.S. chlor-alkali industry now amounts to about 12.5 million tons per year.

In the U.S., nearly one fourth of all the chlorine consumed goes into vinyl chloride. It is by far chlorine's largest market. Second place goes to pulp and paper, which accounts for 14% of chlorine demand. The remainder of the chlorine goes into many diverse, and much smaller markets. But it has been the strength of the vinyl chloride and pulp and paper markets, says Clinton, that has driven U.S. chlorine demand for the past few years.

That's about to change. Environmental concerns will put a crimp in some chlorine uses, such as chlorofluorocarbons (CFCs), solvents, and especially pulp and paper. Clinton estimates that chlorine demand in the pulp and paper industry will decline about 8.6% per year through 1994.

Last year, pulp and paper consumed 1.8 million tons of chlorine. By 1994, that volume will fall to 1.1 million tons. That's a hefty 700,000 tons, or almost 40% decline.

Meanwhile, concerns about possible ozone depletion also will adversely affect chlorine demand. Some CFCs are being phased out. Others are being reformulated using less, and in some cases no, chlorine.



To appreciate the impact these developments may have on chlorine, Clinton notes that about 300,000 tons of chlorine consumption would be lost if 1,1,1-trichloroethane output were halted by legislative or regulatory action.

Obviously, chlorine marketers face some tough problems. But Clinton believes these potential losses will be more than offset by growth in the ethylene dichloride-vinyl chloride-polyvinyl chloride chain. These products will have the greatest impact on world chlorine demand. Chlorine demand for this market probably will increase 4.3% annually. But Clinton thinks that in the Far East the growth will be much more rapid.

Other fast growing chlorine markets include titanium dioxide and isocyanates. Along with vinyl chloride, these markets are expected to support about a 1% per year growth in chlorine demand through 1994 in the U.S. Globally, growth will be a little higher—about 1.5 to 2.0%.

Caustic soda is a different story. Pulp and paper is caustic's largest market—about 24% of the total. But, unlike chlorine, caustic demand in pulp and paper is growing, albeit slowly. The fastest growing markets for caustic will be petroleum (3% annually) and water treatment (2% annually). Together these outlets will give caustic markets overall annual growth rates of 1.5% in the U.S. and between 2 and 2.5% worldwide. Both are slightly higher than chlorine's growth rates.

In addition to pulp and paper, such markets as bleach, alumina, propylene oxide, and general chemicals will be the driving forces behind caustic demand, says Clinton. Export demand, he adds, will put additional pressure on producers' ability to supply enough material.

Between now and 1994, Clinton expects chlorine-caustic plants to operate between 92 and 96% of capacity. This estimate, however, does not take into account any plant rationalization that may take place as chlorine demand dips. During the first quarter of 1990, operating rates were in the "mid-90% range," says Clinton. He pegs chlorine production this year at only slightly higher than last year's 11.9 million tons. □

Thermoplastic color concentrates face challenges

The companies that supply thermoplastic color concentrates to plastics processors have enjoyed a strong run during the second half of the 1980s. Sales have increased from $675 million in 1985 to $875 million last year—a 6.7% per year growth.

The outlook for the first half of the 1990s looks bright, too, says Benjamin D. Berkman, vice president of PMS Consolidated, Coral Springs, Fla. Sales of thermoplastic color concentrates are expected to increase to $1.14 billion by 1995. But this means that the annual growth in sales will taper off to about 4.5%.

More importantly, it implies that producers of thermoplastic color concentrates will have to cope with several critical issues and challenges if they hope to remain in business. Among them:

- Regulatory issues that will shrink the color "palette" for plastics applications.
- Cost of complying with environmental regulations.
- Critical supply of key raw materials.
- Proliferation of specifically tailored new and/or modified polymers.
- Plastics processors' continued conversion from precolored resin to color concentrates.

Despite these problems, Berkman told a recent meeting of the Chemical Marketing Research Association in New York City, demand for plastic materials is far higher now than could reasonably have been expected at the beginning of the eighties. The problems that polymer producers and plastics processors have in handling dust and potentially hazardous pigments and chemicals have provided color concentrate producers with a strong and sustained period of growth.

U.S. output of these thermoplastic color concentrates has increased from 338 million lb in 1980 to 500 million lb in 1989. Growth in production has perked up from 3.2% annually in the early 1980s to 5.4% per year in the second half of the decade. Berkman defines a thermoplastic color concentrate as a plastic compound that contains a high concentration (greater than 20%) of one or more pigments predispersed in a carrier and supplied in pellet form. They are used with natural (uncolored) resins to achieve the desired color when the mix of natural resin and color concentrate is converted into a final product.

Berkman credits the healthy economic conditions that persisted in the U.S. throughout most of the eighties for much of this growth. These conditions sustained a high demand for plastics and, consequently, a high demand for color concentrates.

Demand was also helped by the increasing use of color in many plastics products earmarked for the consumer market. While this demand for more color was taking place, many plastics compounders were moving away from dry pigments, favoring precolored resins instead.

Meanwhile, color concentrates have experienced an almost explosive growth in engineering thermoplastics. Demand for engineering resins is expected to increase from $35.8 million in 1985 to $54 million this year, then mushroom to a hefty $83 million by 1995. Although that still will leave the engineering resin market far behind the commodity resins, such as low- and high-density polyethylene, polypropylene, polyvinyl chloride, and polystyrene, it still represents a sizable and growing outlet.

This growth in engineering resins has been spurred by two changes in coloring nylon, says Berkman. First is the growing preference for concentrates rather than dry pigments to precolor nylon. And more color concentrate is being used to color nylon fiber before it is made into carpet or fabric. In this instance, color concentrate is replacing traditional textile dyeing in yarn and/or piece goods.

The packaging industry has given a big boost to the use of color concentrates in high-density polyethylene (HDPE). As color became more important—either to differentiate among products or to attract consumer attention—concentrate use in HDPE has increased substantially. But the cost of color concentrates has risen faster than volume.

Low-density polyethylene is the largest use of thermoplastic color concentrates . . .

$ Millions	1985	1990*	1995*
High-density polyethylene	115.5	162.0	204.0
Low-density polyethylene	166.3	209.0	250.0
Polypropylene	88.0	126.0	162.0
Polyvinyl chloride	136.8	176.0	215.0
Acrylonitrile-butadiene-styrene	20.0	29.0	40.0
Polystyrene	80.4	100.0	128.0
Polyethylene terephthalate	11.0	15.0	21.0
Engineering resins	35.8	54.0	83.0
Other	21.2	29.0	36.0
TOTAL	675.0	900.0	1139.0

. . . and packaging is their biggest single market

$ Millions	1985	1990*	1995*
Building & construction	105.2	126.0	149.0
Consumer products	106.0	134.0	166.0
Electrical and electronic	63.8	83.0	109.0
Packaging	297.4	411.0	531.0
Transportation	57.8	92.0	121.0
Furniture & furnishings	44.8	54.0	63.0
TOTAL	675.0	900.0	1139.0

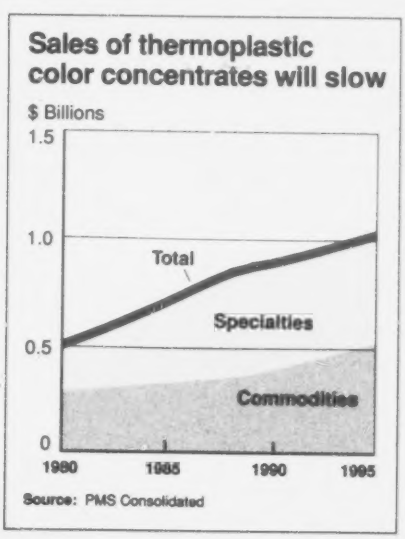
a PMS Consolidated estimates. Source: PMS Consolidated

In addition to HDPE, compounders have moved away from dry pigments toward color concentrates to precolor low-density polyethylene (LDPE) and acrylonitrile-butadiene-styrene (ABS) resins. The driving force: concern about safety and health regulations. In particular, color concentrates have become increasingly popular in in-plant coloring of ABS-molded auto parts.

Berkman believes that color concentrates have a lot of potential in the transportation market. Interior plastic trim in cars and small trucks is almost totally colored with concentrates. And interior carpet and fabric will become a rapidly growing market as automotive fabric manufacturers turn to pigmented fibers to meet new specifications for fade resistance. However, Berkman says the large, long-range potential for color concentrates in automotive applications parallels plastics' penetration into exterior body parts. This, in turn, will be driven by car companies' desire to eliminate the need for painting.

Despite the prospects for growth in thermoplastic color concentrates demand, producers will find several rocks in the road to prosperity. One of those rocks is the regulatory issues that threaten to shrink the color palette in plastics.

Berkman says the initial thrust—to eliminate lead-based pigments—has now blossomed into a full-scale drive to eliminate all heavy-metal pigments for most plastics products, and to eliminate them as hazardous raw materials from plants such as those that produce color concentrates. And the list of usable organic pigments is getting shorter as data show that some of them degrade into hazardous materials when exposed to elevated temperatures and mechanical shear in plastics processing plants.



It may be possible to formulate around some of these problems, says Berkman. Nevertheless, he points out that some strong, vibrant color effects that are now popular in many consumer products will be duplicated only at greater expense or not at all.

Another problem facing color concentrates producers is the high cost of complying with Occupational Safety & Health Administration and Environmental Protection Agency regulations governing worker exposure to dust and other potentially hazardous materials, as well as with regulations governing disposal of plant effluent and solid waste. In fact, Berkman wonders if some of the smaller concentrates companies will be able to shoulder these costs and whether they can afford to clean up contaminated land surrounding older units. He thinks there's a good chance that the number of small, independent producers will shrink. Some may consolidate.

Raw material supply is also becoming a problem for color concentrates companies. As heavy-metal pigments are eliminated, and the color concentrates industry depends more on organic and mixed-metal oxide pigments, it will compete more heavily with the paint and coatings industry for these materials. Berkman also suspects that foreign pigments producers may enter the U.S. color concentrates industry, either through acquisition or with a new facility.

As new polymeric alloys proliferate, and as changes are made in traditional polymers to meet new performance standards in niche markets, Berkman expects that color concentrates producers will find themselves in the "interesting, but possibly precarious position" between the polymer producer and the plastics processor. In the early stages, he explains, the concentrate company will be asked to produce colorants for new polymeric materials so that they can be marketed as precolor compounds.

Because of the unique characteristics of the new polymers, traditional colorant formulations will not do. Color concentrates producers will have to increase their R&D. Then, as the new polymers mature and as plastics processors convert from precolor compound to in-house coloring of the natural resin, the color concentrates company will face a new set of problems. The plastics processor, says Berkman, will look to its color concentrates supplier for the polymer technology, colorant know-how, and processing experience that it needs to produce a high-quality colored plastic part at the lowest possible cost.

Earl Anderson

Taiwan's chemical industry looks overseas

Taiwan has developed a successful integrated petrochemical industry over the past three decades by back-integrating from finished product to raw material and, in some cases, to basic feedstock. Now the industry must face several problems that could put a crimp in the fabulous growth rates to which it has grown accustomed.

One problem is that Taiwan doesn't have enough ethylene or aromatics capacity to satisfy demand from existing derivatives plants, much less those that will be built over the next few years. But land suitable for building new petrochemical complexes in Taiwan is becoming increasingly scarce and expensive. Environmentalists' opposition to new plants is mounting. And labor shortages have developed.

One way Taiwanese chemical companies are coping with these problems is to set up operations outside Taiwan, says Wenent P. Pan, director of Chinese Petroleum Corp.'s corporate planning division. Taiwan's capital investment in Southeast Asia alone, which was only $400 million in 1987, totaled more than $4 billion over the past two years.

Goodyear photo

Rubber Chemicals Industry Strong, Slowly Growing Despite Changes

Stephen Stinson,
C&EN Northeast News Bureau

In the past five years, the U.S. rubber-processing chemicals industry has been turned upside down. Many of the supplier companies have suffered raids, mergers, restructurings, and breakups. And the domestic tire industry, which uses the largest amounts of these chemicals, has likewise changed in ways that reduced the number of producers and left all but one foreign-owned.

But though these changes have been wrenching, they may have left both industries stronger. A reduction in the number of chemical suppliers has eased competition, enabling the survivors to earn respectable profits in the very slowly growing market. In fact, the staff of Uniroyal Chemical Co., who went through a hostile raid, friendly takeover, and management buyout, found time to increase their share of the U.S. rubber processing chemicals market from 8% to 18%.

And the conversion of the U.S. tire industry to multinational, if foreign, ownership has enabled globally sited chemical firms to centralize marketing efforts.

Continuing pressures to protect the environment have shifted investment from development of new products to cleaning up plants and improving processes. Many rubber-processing chemicals are based on odorous sulfur compounds and aromatic amines. During these eventful five years, new funds have gone to

upgrade existing plants, build new plants around environmentally advanced designs, and develop cleaner routes to existing chemicals.

Further impetus to improve plants and processes comes from the rubber industry, whose managers want tighter specifications and narrower variation in processing chemicals. For chemical suppliers, these past five years have seen the introduction of statistical process control, intensified lot-to-lot testing, and monitoring of their processes by their rubber company customers.

What efforts there are to develop new chemicals stem from recent concern over carcinogenic nitrosamines. Though only West Germany has set numerical limits on these concentrations to date, U.S. chemical producers and rubber fabricators are gearing up for possible regulations in this country.

Certain accelerators of vulcanization are susceptible to reaction with airborne nitrogen oxides, and, via nitrosation, become nitrosamines. At issue are not only nitrosamine concentrations in rubber factory air but also in tire warehouses and car trunks where the spare tire sits. The solution may be switching to other existing accelerators or development of new ones that lack susceptibility to nitrosation.

Thus, though the next five years may lack the high drama of the past five, the issues of cleaner plants and processes, higher chemical product quality, and nitrosamines will keep U.S. rubber-processing chemical producers very busy.

C&EN estimates the domestic rubber industry will use 245 million lb of organic processing chemicals in 1990, worth $395 million, compared with 235 million lb in 1989 at a value of $380 million. Of 1990 consumption, 61% by weight will be antioxidants and antiozonants, 34% will be vulcanization accelerators, and 5% will be others such as peptizers and blowing agents.

One gauge of the volume of such a market is that if all the 200-odd substances rubber compounders use to make vulcanized rubber were produced as one substance, its volume would be only one quarter of the amount needed to make it number 50 on C&EN's list of the Top 50 chemicals. And if one firm produced that substance as its sole activity, the dollar value would make that firm only number 84 on C&EN's list of the Top 100 chemical producers.

Yet about 23 U.S. producers plus dozens of distributors for American and foreign companies vie for a share of this market. Of these firms, Monsanto, Uniroyal, Mobay, and Goodyear sell 85% of U.S. needs.

Although 1990 consumption of rubber-processing chemicals will probably be 245 million lb, it is almost impossible to estimate U.S. production for foreign trade. This is because the U.S. International Trade Commission stopped tabulating imports in 1983, and the Bureau of the Census ceased publishing figures on exports in 1988.

The U.S. ITC does publish annual reports of production and sales of rubber-processing chemicals, but most industry analysts discount these as unreliable. This may be because some rubber antioxidants are also gasoline, lubricating oil, and plastics additives. And some derivatives of dithiocarbamic acid are fungicides as well as vulcanization accelerators.

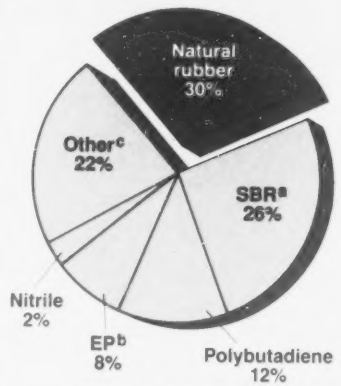
The U.S. ITC reports domestic production of rubber-processing chemicals was 318 million lb in 1989. This seems very high in view of the tight production capacity in this country, possible imports in the neighborhood of 10 million lb, and the consequent inability to export almost 100 million lb.

C&EN estimates that in 1989, Monsanto Chemical Co. of St. Louis produced 92 million lb of rubber-processing chemicals for the domestic market. The company sold 68 million lb of this to tire makers, and 24 million lb was distributed to the nontire rubber industry by Harwick Chemical Corp., Akron, Ohio.

Uniroyal of Middlebury, Conn., made and sold 42 million lb in the U.S. alone in 1989. Mobay Chemical Corp., Pittsburgh, Pa., produced and imported 38 million lb, selling most of that itself and marketing perhaps 5 million lb through distributors.

Akron-based Goodyear Tire & Rubber Co., a tire maker, and B. F. Goodrich, formerly a tire maker, both produce rubber-processing chemicals and sell them in a three-way relationship with R. T. Vanderbilt Co., Norwalk, Conn., which is itself a chemicals producer. According to the agreement, Goodyear sells its antioxidants and antiozonants (perhaps 14 million lb in 1989) through its own sales force and distributes its accelerators (possibly 10 million lb) through Vanderbilt. Goodrich distributes its antioxidants and antiozonants (perhaps 5 million lb in 1989) through Vanderbilt and its accelerators (possibly 7 million lb) through Akron Chemical Co. For its part, Vanderbilt may have made 7

Natural rubber holds a 30% share of consumption



1989 total U.S. rubber consumption = 6.6 billion lb

a Styrene-butadiene rubber. b Ethylene-propylene rubber. c Includes butyl, polyisoprene, polychloroprene, and silicone rubbers. **Source:** Rubber Manufacturers Association

Antidegradants make up the largest class of rubber-processing chemicals

Type	U.S. consumption, millions of lb					
	1986	1987	1988	1989	1990	1995
Antidegradants[a]	136.3	144.2	148.4	144.5	150.8	164.9
Accelerators[b]	74.7	79.1	81.4	79.2	82.6	90.4
Miscellaneous[c]	11.1	11.7	12.0	11.7	12.2	13.4
TOTAL	222.1	235.0	241.8	235.4	245.6	268.7

a Antidegradants include antioxidants and antiozonants. b This category includes vulcanization accelerators, retarders, and organic sulfur donors. c Miscellaneous chemicals include peptizers and blowing agents. **Source:** C&EN estimates

million lb of rubber-processing chemicals in 1989.

A slowly but steadily growing presence in rubber-processing chemicals is Akzo Chemicals of Chicago, a subsidiary of Akzo in Arnhem, the Netherlands. Its 1989 sales may have been a little less than 10 million lb in the U.S.

Akzo Chemicals has owned the former Noury Chemicals of Burt, N.Y., makers of organic peroxides, since 1972. Though used mostly as initiators of polymerization and curing of unsaturated polyesters, some peroxides are vulcanizing agents for specialty rubbers.

Akzo acquired the insoluble sulfur business of the former Stauffer Chemical Co. from ICI in 1987, and also acquired a French rubber chemical company called Vulnax. In 1989, it picked up the accelerator-chemicals plant of Pennwalt Italia in Termoli.

Most recently the company has announced a $30 million, 25 million lb-per-year plant to make 2-mercaptobenzothiazole accelerator in LeMoyne, Ala., due on stream late in 1991. In line with current environmental concerns, the plant will use a process that cuts by-products by 50%. Of the process, which seems to involve the usual reaction of aniline, carbon disulfide, and sulfur, company spokesmen say only that it involves a catalytic oxidation.

The beginning of the new era for the U.S. tire industry and its processing chemicals suppliers began in 1985 when Uniroyal, which was then a tire, chemical, and plastics company, attracted an unwanted

What rubber-processing chemicals are

The rubber-processing chemicals described in this report are the 200-odd organic substances that rubber compounders use to make vulcanized rubber products. With the exception of such goods as adhesives and crepe rubber shoe soles, raw, unvulcanized rubber has no commercial uses.

This report covers accelerators, used to speed the crosslinking reaction with sulfur; activators, used to potentiate the accelerators (sometimes called secondary accelerators); retarders, used to delay vulcanization; organic sulfur donors and peroxides, used as vulcanizing agents; peptizers, used to reduce rubber polymer viscosity; and antioxidants and antiozonants (collectively called antidegradants), used to protect rubber during processing and afterward in use. Rubber compounders use an average of 4.5 lb of these rubber-processing chemicals per 100 lb of rubber.

Organic compounds not covered in this report include mercaptans that regulate polymerization of monomers to synthetic rubber, those peroxides that initiate such polymerization, fatty acid activators, and various oils and asphalt used as physical plasticizers and extenders.

Among inorganic compounds excluded from this report are elemental sulfur as a vulcanizing agent, zinc oxide and other oxide activators, carbon black, silica, and clay reinforcements and fillers.

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Rubber heads for 500th birthday

1495. In perhaps the first mention of rubber in Europe, Michele de Cuneo returns from Columbus' second voyage and writes, in Hispaniola "there are also trees that when cut give milk, of which [the Indians] make something like wax, and we have tried it out."

1521. Hernando Cortés in Mexico sees the Aztecs using a gum from trees to waterproof utensils and make balls for games. Spanish colonists also use the gum for waterproofing, but for the next 300 years it appears in Europe only as balls and other curiosities.

1750. After a 14-year search in South American jungles, engineer François Fresneau discovers the rubber tree, *Hevea brasiliensis*. Astronomer Charles de la Condamine reads Fresneau's paper to the French Academy, using the Indian word caoutchouc, derived from caa (tears) and ochu (wood).

1770. Joseph Priestley writes that the gum makes a good "rubber" to erase pencil marks, but he is probably not the first to use the word.

1819. Inventor Thomas Hancock develops solvent processing, and the manufacture of rubber articles begins in England. Products eventually include the raincoat of Charles Macintosh (1823) and waterproof shoes. Hancock also builds a machine that renders rubber more tractable, thus inventing mastication. But rubber goods are inferior, becoming sticky in summer and brittle in winter.

1839. Charles Goodyear accidentally finds that heat cures a compound of rubber, sulfur, and lead carbonate to a hard, resilient, infusible solid. Hancock discovers the process independently and coins the term vulcanization. Goodyear gets a patent, U.S. 3633, June 15, 1844.

1876. Coffee planter Henry Wickham smuggles 70,000 Hevea nuts out of Brazil, which until now has had a monopoly of world rubber production. The British send 3000 seedlings grown in Kew Gardens to start plantations in Ceylon and Malaya. By 1900, plantings reach 4000 acres in those lands.

1888. Veterinarian John Boyd Dunlop makes pneumatic bicycle tires. Extension of this idea to automobile tires will make the fortunes of both the rubber and auto industries.

1906. Chemist George Oensager at Diamond Rubber Co., Akron, Ohio, discovers that aniline accelerates vulcanization. Though abandoned as too toxic, the compound becomes the first in a long line of organic accelerators in coming decades.

1910. Recent invention of the automobile stimulates production of more than 200 million lb of rubber per year as prices skyrocket to $3.12 per lb. German chemistry professor Carl Dietrich Harries at the University of Kiel finds that sodium catalyzes polymerization of 2,3-dimethylbutadiene to a synthetic "methyl rubber."

1918. By the end of World War I, Germany has produced a total of 5 million lb of methyl rubber.

1927. Chemists at Bayer develop Buna S (butadiene-natrium-styrene) rubber, inspired by work of chemistry professor Karl Ziegler at Heidelberg University. In the U.S., J. C. Patrick tries to make ethylene glycol by hydrolysis of ethylene chloride in alkaline sodium polysulfide solution. He ends up inventing polysulfide rubber instead, and Thiokol Chemical Corp. is founded to produce it in 1929.

1931. Du Pont announces neoprene, a synthetic rubber made from chloroprene, whose commercial synthesis has been developed by Wallace H. Carothers.

1942. Cut off from supplies of natural rubber, the U.S. government orders the planting of 75,000 acres of latex-producing guayule shrub. After World War II, work on guayule will be abandoned. U.S. industry gears up to make various synthetic rubbers and reaches a capacity of 1.5 billion lb per year by 1945.

1950. The U.S. Army takes World War II jeeps out of mothballs for the Korean War but finds the tires have deteriorated. Studies pinpoint ozone as the cause and lead to development of organic antiozonants.

1973. U.S. consumption of natural rubber has bottomed out at 22% of all rubber used. But now the Arab oil embargo and a series of steep rises in olefin prices tilt the balance against synthetic rubber during the decade.

1990. World rubber production reaches 25 billion lb, 37% of it natural. The U.S. consumes 6.4 billion lb, 27% of which is natural rubber. To fabricate this amount of rubber, the U.S. uses 245 million lb of organic rubber-processing chemicals.

takeover bid from New York City investor Carl Icahn. To escape, Uniroyal's management agreed to allow the company to be acquired by the New York City investment firm of Clayton & Dubilier.

In 1986, Uniroyal and its new owners agreed with Goodrich to merge their tire-making operations into a joint venture, Uniroyal Goodrich Tire Co. of Akron. Later that year, Uniroyal sold Uniroyal Chemical Co. to a publicly held investment company called Avery. Finally in 1989, Uniroyal Chemical was taken private in a leveraged buyout by its managers, the same group that had not only survived since 1986 but that had made the company thrive.

Meanwhile in 1988, Goodrich sold its share in Uniroyal Goodrich Tire Co. to Clayton & Dubilier, which had retained the other half. Three weeks ago, Clayton & Dubilier completed the sale of the tire company to the French firm, Michelin Group.

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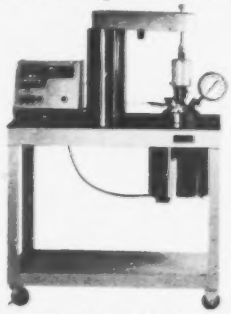

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In 1986, English investor Sir James M. Goldsmith and the London-based investment company, Hanson Industries, proposed a takeover of Goodyear. The company responded with a vigorous restructuring and a tender offer for its own shares. Also, the state of Ohio passed a series of laws to let Ohio companies force sales of their own shares from selected shareholders in return for other securities, and to finance sales of their own shares to third parties. The English partners then agreed to sell their shares to Goodyear.

Also in 1986, Borg-Warner, Chicago, became the object of a bidding war between Minneapolis investor Irwin L. Jacobs and GAF for a hostile takeover. Among its other activities, Borg-Warner's Morgantown, W.Va., plant produced phosphite ester stabilizers and phenolic antioxidants for rubber.

Though Jacobs dropped out in March 1987, GAF persisted until Borg-Warner's management agreed that the company would be acquired by the investment group, Merrill Lynch Capital Partners, a month later. GE Plastics, a division of General Electric Co., bought the rubber chemicals business along with Borg-Warner's plastics in 1988.

Also in 1988, Pennwalt of Philadelphia came under attack from New York City-based Centaur Partners. Pennwalt's managers spent the year selling off assets, including Pennwalt Italia, to Akzo, in an effort to restructure the company. But Centaur Partners continued, and Elf Aquitaine of France acquired an attenuated Pennwalt in a friendly takeover in 1989 and merged it into its Atochem North America subsidiary. Included in Atochem North America is the former Lucidol Division of Pennwalt, Buffalo, N.Y., which makes organic peroxides.

While these changes were going on in the rubber-processing chemicals industry, the domestic tire and rubber industry also underwent change. The upshot has been to leave Goodyear and Cooper Tire & Rubber Co. as the only independent major American rubber companies.

In addition to the Michelin purchase of Uniroyal Goodrich Tire Co. this year, Continental Gummiwerke of West Germany acquired General Tire & Rubber Co. in 1987. Bridgestone of Japan bought Firestone Tire & Rubber Co. in 1988, and in the same year, Pirelli of Italy purchased Armstrong Rubber Co. In 1990, Yokohama Rubber Co. of Japan bought Ohio-based Mohawk Rubber Co.

This worldwide consolidation of rubber and tire production, which industry observers call globalization, is leading also to standardization both in the rubber industry and in the processing chemicals industry that supplies it. For example, Walter J. Cook of Uniroyal Chemical says his company thinks in terms of a world tire.

Cook, who is Uniroyal's vice pres-

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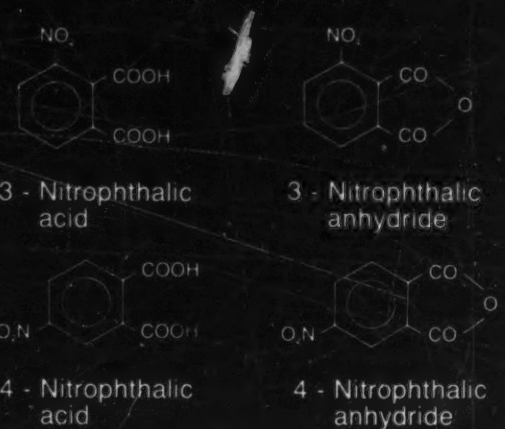

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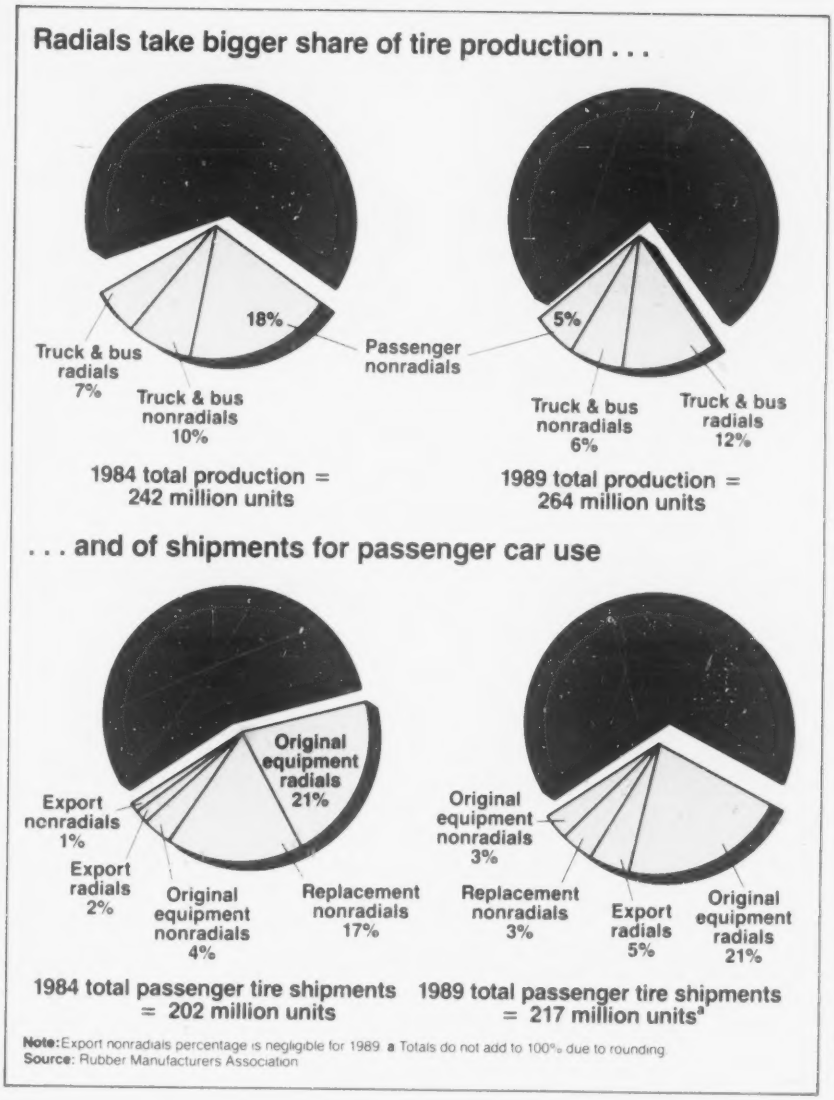
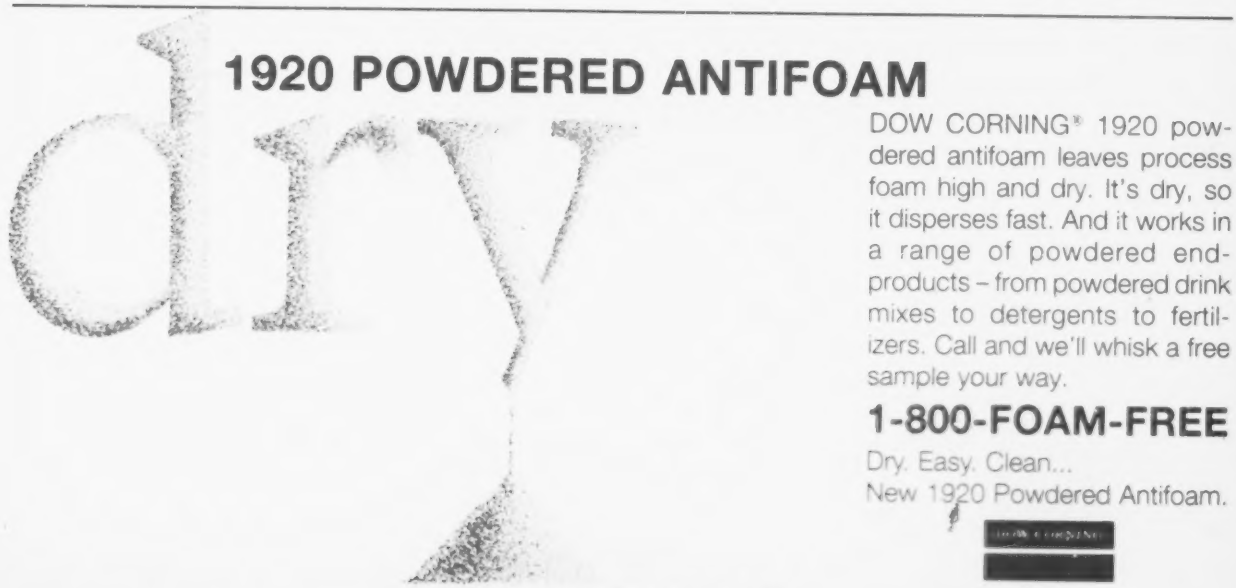

Radials take bigger share of tire production . . .
Truck & bus radials 7%
Truck & bus nonradials 10%
18%
Passenger nonradials
1984 total production = 242 million units
5%
Truck & bus nonradials 6%
Truck & bus radials 12%
1989 total production = 264 million units
. . . and of shipments for passenger car use
Export nonradials 1%
Export radials 2%
Original equipment nonradials 4%
Original equipment radials 21%
Replacement nonradials 17%
1984 total passenger tire shipments = 202 million units
Original equipment nonradials 3%
Replacement nonradials 3%
Export radials 5%
Original equipment radials 21%
1989 total passenger tire shipments = 217 million units[a]
Note: Export nonradials percentage is negligible for 1989. a Totals do not add to 100% due to rounding.
Source: Rubber Manufacturers Association

ident and general manager for chemicals and polymers worldwide, also cites the effects of the relatively recent "transplant" phenomenon. Transplant is the name first given to U.S. production plants of Japanese automakers. But in Cook's parlance, transplants are auto and tire factories of any country in any other country, including those springing up in the Third World.

Cook points out that transplant automakers demand the same high, narrowly standardized quality tires that their parent companies buy for their western production. And transplant tire makers demand the same high, narrowly standardized quality chemicals that their parents use at home. Moreover, tire companies want to be able to ship tires they make in any country to any other country with complete confidence of acceptability.

Thus the same five years that have changed the structure of the rubber processing chemicals industry also have seen the manner of producing and selling these chemicals change. Roger K. Price, who is vice president of Vanderbilt's Rubber Chemicals & Minerals Group, described how the new situation has affected his company.

Nowadays Vanderbilt sends out a certificate of analysis with every chemical shipment to 1700 customer locations. Price contrasts this activity with that of five years ago, when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Glossary of rubber-processing chemicals terms

Accelerator. Speeds crosslinking of rubber by sulfur. Example: 2,2′-dithiobis-(benzothiazole).

Activator. Renders accelerators more potent. Example: zinc oxide with stearic acid. Alternatively, a secondary accelerator that is an accelerator in its own right but is mostly used with others. Examples: thiurams, dithiocarbamates, and guanidines.

Antidegradant. Inclusive term to denote antioxidants, antiozonants, and stabilizers.

Antioxidant. Protects cured rubber products against oxidative degradation in service. Examples: *N*-isopropyl-*N*′-phenyl-*p*-phenylenediamine, which is also an antiozonant, and octylated diphenylamine, which is not. Antioxidants that protect synthetic rubber during processing are called stabilizers.

Antiozonant. Protects cured rubber products against ozone. Examples: waxes, which migrate to the surface to form a physical barrier, and *N,N*′-bis(1,4-dimethylpentyl)-1,4-phenylenediamine, which protects by chemical reaction.

Blooming. Unwanted migration of such substances as sulfur to rubber surfaces to produce discoloration.

Bonding agent. Enhances adhesion of rubber to fabric or fiber.

Cure. Crosslinking of rubber polymer chains to impart elastomeric properties. Also called vulcanization.

Cure time. Time needed for rubber compounds to reach maximum viscosity or elastic modulus at a given temperature. The sum of the scorch time and crosslinking time.

Hard rubber. Rubber cured with 15 to 40% of added sulfur.

Latex. Water emulsion of rubber polymer, used as is for coatings or dewatered to make solid parts.

Lubricant. Eases flowing of rubber in molding or extrusion.

Mastication. Preliminary physical and

only 10 customer locations demanded such attention. Vanderbilt also compiles quarterly reports for customers of upper and lower limits of various process parameters according to statistical process control so that customers can verify how stable Vanderbilt's processes are.

Demands of the recent quality regime are reflected in the $6 million, 50% expansion of Vanderbilt's chemical plant in Murray, Ky., which opened a year ago. Pneumatic valves and electrical relays have given way to electronic controls. A central computer not only drives programable logic control modules but also accumulates data for statistical process control charts for quality control reports to customers.

One organization that is profiting from the drive for quality and narrow standards is Monsanto Instruments & Equipment, Akron, Ohio. In 1988 the company introduced three microprocessor-controlled instruments and two software packages for data analysis.

The moving die rheometer—MDR 2000—and the oscillating die rheometer—ODR 2000—are each priced at $40,000. The Mooney viscometer MV 2000 sells for $28,000. To enhance capabilities of these, RheoLogic and MooneyLogic are available in many individual configurations for about $10,000 each, a price that includes the recommended IBM PS/2 Model 30 microcomputer to run them. These products join the somewhat older microprocessor-controlled Tensometer 10 ($19,800) and TensiLogic ($10,000).

As Monsanto Instrument's markets and products manager Jack Hanley puts it, "What happened to us from the mid-80s is that we started hearing a lot of noise from the marketplace. Customers wanted more precise results, and customers wanted better productivity from the instruments they were using. And that essentially drove us to the Series 2000."

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chemical breakdown, usually of natural rubber, in a mill or mixer to reduce viscosity for further processing.

Peptizer. Promotes chemical breakdown of rubber during mastication. Also called a plasticizer. Example: pentachlorothiophenol.

Phr. Parts per hundred rubber. The number of parts by weight of substance added to 100 parts of rubber.

Plasticizer. A peptizer, oil, or monomeric ester softener or extender. Example: bis(butoxyethoxyethyl) glutarate.

Retarder. Lengthens the amount of time before onset of the curing process. Example: phthalic anhydride. Sulfenamide-type retarders have acquired the separate name of prevulcanization inhibitors. Example: *N*-cyclohexylthiophthalimide.

Reversion. Decrease in rubber elastic modulus or viscosity caused by overworking.

Scorch. Premature curing.

Scorch time. Safety margin of time that a rubber compound can be worked at a given temperature before curing begins.

Soft rubber. Rubber cured with 0.5 to 8% of added sulfur.

Stabilizer. Antioxidant that protects rubber between the polymerization and curing steps. Example: tris(nonylphenyl) phosphite.

Staining. Blue or purple coloration of rubber surfaces owing to oxidation of phenylenediamine-type antioxidants and antiozonants.

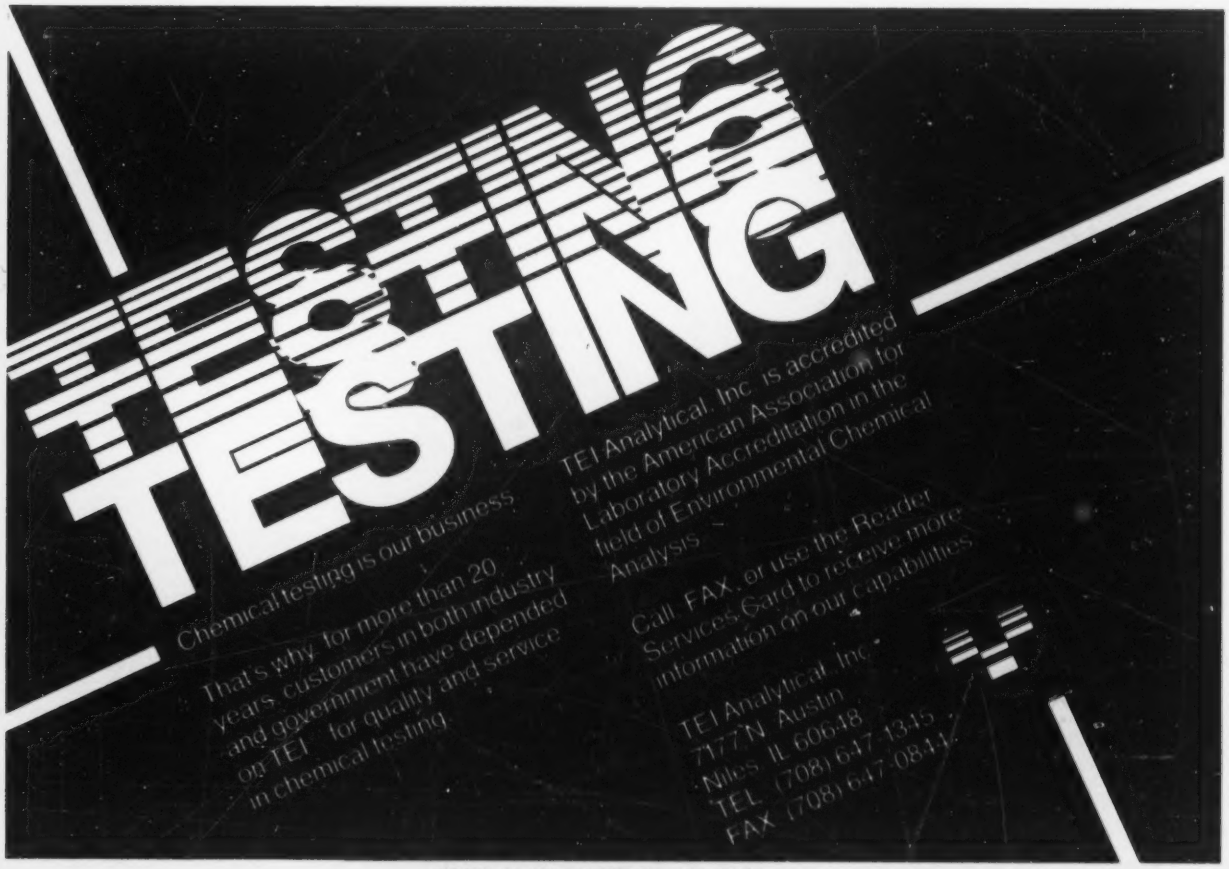
Sulfur donor. Organic polysulfide that replaces some elemental sulfur in rubber compounds and promotes curing mostly by monosulfide crosslinks in a process called efficient vulcanization. Example: tetramethyldithiuram disulfide.

Vulcanizing agent. Cures rubber by forming crosslinks among polymer chains. Examples: sulfur, organic peroxides, and phenolic resins.

The more precise results come from microprocessor control, which ensures reproducible heating back up to test temperature. Fast heating minimizes operator variation. The rheometers also measure torque by a new method with greater precision than other instruments. And dynamic calibration comes from use of a torque standard.

The better productivity results from shorter times to do each test. This is because dies are directly heated, the temperature is self-calibrating, calculation of standard data points is automatic, and a new die design eases sample removal.

For the future, Monsanto will capitalize on two growth trends: siting of test instruments on production floors and customers' desires for ro-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botics for testing. The new instruments have membrane keyboards, which can endure production conditions.

Says Hanley, "We're recognizing that some of our customers have installed our instruments directly in the production environment. This, of course, is a change of philosophy on their part, where they're trying to get the process control more into the process and having the operator of the mixer or the process itself engaged with measuring the quality of the material."

Hanley further declares, "Sometime within the next year we will market a dedicated robot." Users will arrange labeling of samples with bar codes. Controlled by a microcomputer, the robot will read the bar code to get instructions, insert the sample into as well as remove it from the sample chamber, and send the resulting data to the user via the computer.

In addition to building and upgrading plants for better process stability and control, rubber processing chemical firms have striven to improve environmental performance of their processes. Akzo's plant at LeMoyne, Ala., will make 2-mercaptobenzothiazole by a new process that greatly reduces effluent. Carl Clay, manager of the rubber department at Mobay Corp., points out that in 1985, parent Bayer of West Germany, decided to devote future capital spending to include environmental upgrading among other improvements to existing plants worldwide.

Price of Vanderbilt says his company has spent $8 million in environmental improvements to its plant in Bethel, Conn. And Vanderbilt's expansion in Murray, Ky., includes facilities to oxidize all sulfur by-products of its processes to sodium sulfate, which is sold to nearby paper mills.

Although process and plant improvements have taken investment away from new product development, there have been some advances. At Goodyear, for example, Roger Hagstrom says the company has introduced a nonstaining antioxidant that is a reaction product of *p*-nonylphenol, dodecanethiol, and formaldehyde.

Hagstrom, who is director of marketing in Goodyear's Chemical Division, also points to a new polymerizable antioxidant, *N*-(4-phenylaminophenyl)methacrylamide. Using about 1.5%, this compound can be copolymerized into styrene-butadiene, nitrile, polybutadiene, acrylonitrile-butadiene-styrene, or neoprene rubbers; grafted at a 1% level onto these rubbers; or added to these rubbers, either as free acrylamide or as a 38% copolymer with butadiene. When added as free acrylamide, it functions as an antihardening agent by trapping free radicals.

Elsewhere at Goodyear, Hagstrom says the firm may introduce new sulfenamide accelerators. Goodyear closed its Akron rubber-processing chemicals plant in 1985, which took the company out of accelerator types made there. Currently, the only accelerator Goodyear produces is 4-morpholino 2-benzothiazolyl disulfide at Niagara Falls, N.Y.

New product opportunities may also arise in the future to replace accelerators that form carcinogenic nitrosamines. Examples of these types of accelerators are tetramethylthiuram disulfide and *N*-oxydiethylene-2-benzothiazolesulfenamide. These compounds may react with atmospheric nitrogen oxides before use, during vulcanization, or in stored vulcanized rubber products to form nitrosamines.

The solution may be to switch to such existing accelerators as *N*-*tert*-butyl-, *N*-cyclohexyl-, or *N*,*N*-dicyclohexyl-2-benzothiazolesulfenamide. Clay of Mobay says Bayer has developed new alternative accelerators. These are experimental compounds still in testing worldwide, however, and Clay adds it is premature to discuss them.

For its part, Akzo has developed tetrabenzylthiuram disulfide. Because of the higher molecular weight of the tetrabenzyl accelerator, it must be used at about 2.3 times by weight when replacing tetramethylthiuram disulfide in order

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R. T. Vanderbilt's Murray Ky., plant has more than 40 miles of pipeline that help maintain a constant flow of chemicals during processing

to furnish the same amount of organic sulfur to develop comparable properties in rubber. This will make use of the tetrabenzyl additive more costly.

Still Akzo scientists are encouraged, because *N*-nitrosodibenzylamine seems not to be carcinogenic. Too, the tetrabenzyl compound itself contains low amounts of that nitrosamine. The concentration of the nitrosamine does not increase during vulcanization. And tetrabenzythiuram disulfide combines lower toxicity (than the tetramethyl derivative) with nonvolatility during storage of rubber products.

In general, U.S. consumption of rubber-processing chemicals rises and falls with the sheer volume of rubber use. Because 60% of rubber goes to make tires, changes in tire-making technology can affect overall patterns of chemical consumption, but only in small ways in comparison with effects of much wider swings in the economy.

Domestic rubber consumption peaked at 7.4 billion lb in 1977, according to the Rubber Manufacturers Association (RMA). After bottoming out at 5.3 billion lb in the long 1979–82 downturn in durable goods, demand only returned to 6.2 billion lb in 1989. The International Institute of Synthetic Rubber Producers (IISRP) has predicted an average annual average increase of 1.5% in North America into the mid-1990s. This could point to use of only 7 billion lb of rubber in the U.S. in 1995.

The smaller changes in domestic use of rubber-processing chemicals in the next five years may be influenced by the continuing trend toward replacement of bias-ply by radial tires, increased production of so-called high-performance, low-profile tires, reversal of the 15-year-old trend toward smaller tire sizes, and the growing number of states that have abolished the 55-mph speed limit.

In the five years from 1984 to 1989, tire production rose to 264 million units from 242 million, according to RMA. During that period, radial tires for passenger cars increased their share to 77% from 65% of all tires produced. And tires for trucks and buses raised their share to 12% from 7% of the total, leading to an increase for all radial tires to 89% from 72%.

Increased production of radial tires has had the effect of slightly decreasing use of rubber-processing chemicals. One reason for this

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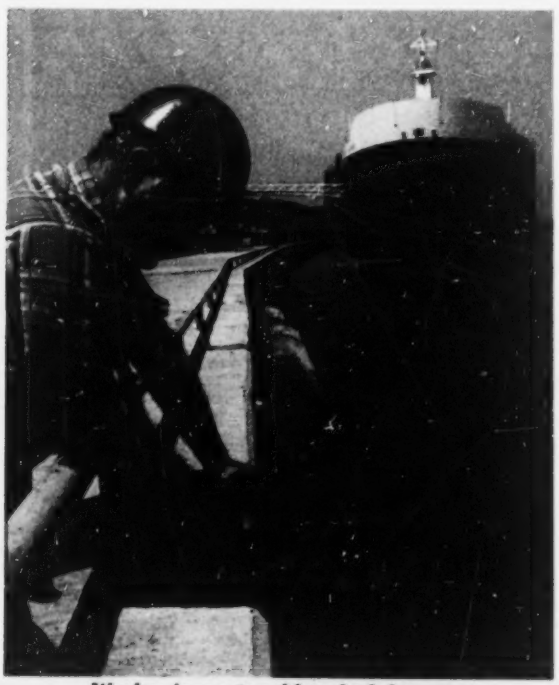
change is that radial tires require larger amounts of natural versus synthetic rubber. Natural rubber contains proteins and lipids, which function as antioxidants, leading, in turn, to decreased amounts of synthetic organic antioxidants needed during fabrication.

A second reason is the longer lifetimes of radials compared with other types, resulting in longer times between replacements. But if natural rubber needs lesser amounts of antioxidants during processing, it requires greater amounts both of antioxidants and antiozonants to protect radial tires in service. This is because oxygen and ozone attack tire rubber even when the car stands in the garage.

Natural rubber does take larger amounts of peptizers than does synthetic. This is because natural rubber has a higher viscosity during fabrication, which those additives help reduce. But even with factoring in peptizers, continued penetration of radials will have an attenuating effect on rubber-processing chemicals use.

There is increasing consumer interest in high-performance, low-profile tires. These tires have a broader area of contact with the road, providing better traction. But these tires require more rubber to build than conventional tires, and the greater contact area gives them less mileage. To the extent that these tires penetrate the market, their greater rubber consumption and shorter times between replacements will expand the rubber-processing chemicals market.



Goodyear photo

Worker inspects rubber dock bumpers

Sizes of cars driven in the U.S. have decreased steadily since 1975, a situation which has meant a decrease in tire sizes also. But, recently, there has been an upturn in the use of larger automobiles, with a consequent demand for larger tires. The adoption of the 55-mph speed limit around 1975 contributed to greater tire mileage. If more and more states raise this limit, tire lifetimes consequently would be expected to go down.

Because markets for rubber-processing chemicals are mainly dependent on fluctuations in economies, the greatest opportunities for U.S. chemical companies may lie in Asia, Latin America, and the centrally planned economies of Europe and Asia, according to forecasts of IISRP. Though an organization of synthetic rubber producers, the institute includes natural rubber in its figures.

In Asia and Oceania (central and south Pacific islands including New Zealand and the continent of Australia), for example, rubber consumption may rise to 9 billion lb in 1994 from 7.9 billion lb in 1990 at an average growth of 2.7% per year. This growth is in contrast to the 1.4 to 1.5% rates expected for North America, Europe, Africa, and the Middle East. In Latin America, demand is expected to reach 1.86 billion lb in 1994, up from 1.64 billion lb in 1990, growing 2.6% annually.

IISRP analysts acknowledge difficulties in predicting the future in the centrally planned economies, which have undergone such profound changes in the past two years. Nevertheless, they put the growth rate at 3.1% per year to estimate rubber consumption of 11.3 billion lb in 1994, as compared with 9.9 billion lb in 1990. □

Rubber handbook redux

Robert Ohm of R. T. Vanderbilt Co. has set the Oct. 9–12 meeting of the Rubber Division in Washington, D.C., as the target for continuing a tradition in the industry, "The Vanderbilt Rubber Handbook." Ohm is technical director of the Rubber Chemicals & Minerals Group and editor of the new edition.

Among changes readers will note are elimination of such fading products as hard and reclaimed rubbers. Hard rubber is cured with about 25 parts-per-hundred rubber sulfur and mixed with high loadings of anthracite coal for molding such parts as battery cases. Reclaimed rubber is salvaged from scrap tires and partially devulcanized by adding oils and treating with steam at about 400 °F. New to the 1990 edition will be tetrafluoroethylene-propylene-diene monomer and polyphosphazene rubbers, as well as membranes for pond and roof liners.

The most recent edition, published in 1978, contained almost 900 pages, and Ohm says the 1990 edition will be about the same. The dozens of contributed articles on individual elastomers, processing chemicals, fabricating technologies, and product types will be rewritten. Ohm has set most of the tables in vertical format so that users need not turn the book to read them.

Undecided for now is whether to add a separate index by trade names to the existing subject index; and whether to include an explanatory listing of the many abbreviations and acronyms current in the industry.

One part of the tradition cannot continue, though. Vanderbilt distributed previous editions of the handbook free as a service to the industry. Rising costs of publication will force the firm to set a per copy price of $100 on the 1990 edition.